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Article

# Optimal Allocation Mechanism for Scarce Public Goods: A Cross-Country Analysis and Key Lessons from COVID-19 Vaccines

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**Abstract** How to optimally allocate COVID-19 vaccines and scarce public goods is a crucial and sensitive question to scholars, policy-makers, and practitioners. The ethical dimensions and principles of vaccine allocation between groups are widely agreed upon, whereas the ethical dimensions and principles of vaccine distribution between countries at the peak of the COVID-19 pandemic are highly controversial. This article aims to investigate how vaccines were globally allocated across countries and propose an optimal allocation mechanism for vaccines and scarce public goods. The results show that, to a certain extent, the global allocation of COVID-19 vaccines was fair and effective. Countries with more cases and deaths obtained more vaccines and vaccinations. Wealthier countries might receive more vaccinations but also suffer more severe consequences of COVID-19. Though COVAX could miss its initial vaccine delivery targets, the facility should be considered successful in its core goals and plays a critical role in controlling the pandemic. The study proposes a fair and effective mechanism of vaccine allocation that combines the roles of markets and interventions of international organizations and national governments with three degrees: *emergency*, *priority*, and *market*.

**Keywords:** optimal allocation; vaccine; scarce public goods; COVID-19; pandemic; COVAX

## 1. Introduction

Decision-making regarding scarce public goods (SPGs) allocation is intrinsically ethical, and so it is directly relevant to the expected professional and multi-dimensional standards and principles, especially related to public health resources during a crisis and urgent period (Armitage, 2022; Rawls, 2020; GMC, 2013; Kazemi et al., 2022). The coronavirus originated in China in 2019 and rapidly spread worldwide with the emergence of various COVID-19 variants. At the peak of the COVID-19 pandemic, there were over 225 million COVID-19 infection cases and over 4.6 million deaths on 12 September 2021 (Mathieu et al., 2021). The USA, India, Brazil, the EU countries, and the ASEAN countries were among the most affected by the COVID-19 pandemic (Worldometers, 2021). The coronavirus not only killed people and caused permanent organ harm but also damaged the health of uninfected people by straining healthcare systems, increasing mortality rates for common conditions, negatively affecting mental health, and accelerating the spread of disease by hindering immunizations. Additionally, the COVID-19 pandemic has devastated the global economy by hundreds of billions of US dollars; caused unemployment, economic decline, poverty, and starvation; and made significant losses to human capital by harming education (Emanuel et al., 2020a; Castillo et al., 2021). The tremendous and rapid increase in COVID-19 cases and deaths made the public health and social measures (PHSMs) ineffective and overloaded. In that situation, the COVID-19 outbreak could be considered uncontrollable by the PHSMs, and vaccination was the key solution. The COVID-19 catastrophe was improbable to finish until there was a global vaccine rollout to obtain herd immunity (Wouters et al., 2021; Hoang, 2022). An effective COVID-19 vaccine should undoubtedly be a global public good as the overarching goal of the global community (WHO, 2020).

However, the manufacturing capacity of efficacious vaccines was limited at the peak of the event. The COVID-19 pandemic could place extraordinary and sustained demands on public health

and healthcare systems, and there was an urgent need to ration medical equipment, interventions, and vaccines in the short and medium terms (Emanuel et al., 2020b). At the pandemic's peak, the concern of unfair and ineffective allocation of vaccines was widely appeared and debated. Researchers warned that it might not be possible to make enough vaccines for all people in the short term, and the wealthiest countries might restrict vaccine export and hoard vaccine supplies to ensure their local vaccinations (Khamsi, 2020; Singh & Chattu, 2021). Leaders of the EC, France, Germany, the UK, Norway, and Saudi Arabia announced public commitments to collaborate as one global community united against the pandemic and to regard COVID-19 vaccines as public goods. However, they also successfully placed themselves at the front of the supply queue, which could delay access to vaccines for less-resourced countries (Bassi, 2021). To ensure fair distribution and prevent hoarding of COVID-19 vaccines, scholars and practitioners have proposed various priority models with ethical dimensions, values, and principles for the fair allocation of COVID-19 vaccines, medicines, and medical equipment (Emanuel et al., 2020a; Liu et al., 2020; Dai et al., 2020). Policy-makers worldwide struggled for a fair balance between different ethical principles of vaccine allocation. However, there were trade-offs; any decision to implement some principles could come at a cost in terms of losses of lives, society, economy, and politics (Marz et al., 2022). Scholars and practitioners have suggested several ethical dimensions, values, and principles for the optimal allocation of COVID-19 vaccines. Table 1 summarizes the key dimensions, values, and principles for COVID-19 fair and effective vaccine allocation at different levels and scopes.

**Table 1.** Summary of ethical dimensions, values, and principles for COVID-19 vaccine allocation.

Authors	Dimensions, Values, Principles
Persad et al. (2009)	<ul style="list-style-type: none"> <li>• Treating people equally: Lottery; First-come, first-served.</li> <li>• Favoring the worst-off - prioritarianism: Sickest first; Youngest first.</li> <li>• Maximizing total benefits - utilitarianism: Number of lives saved; Prognosis or life-years saved.</li> <li>• Promoting and rewarding social usefulness: Instrumental value; Reciprocity.</li> </ul>
National Academies of Science Engineering & Medicine (NASEM, 2020)	<ul style="list-style-type: none"> <li>• Ethics: maximum benefit, equal concern, mitigation of health inequity.</li> <li>• Procedure: fairness, transparency, and evidence-based.</li> <li>• Allocation criteria: risk of (1) acquiring infection, (2) severe morbidity and mortality, (3) negative societal impact, (4) transmitting the infection to others.</li> </ul>
WHO (2020a)	<ul style="list-style-type: none"> <li>• Human well-being, equal respect, global equity, national equity, reciprocity, and legitimacy.</li> <li>• Target groups: People with a high risk of severe disease or death, people with a high risk of being infected, people with risks, and to safeguard others.</li> </ul>
WHO (2020b)	<ul style="list-style-type: none"> <li>• Ethical considerations: equality, best outcomes (utility), prioritizing the worst off, and prioritizing those tasked with helping others.</li> </ul>
Emanuel et al. (2020a)	<ul style="list-style-type: none"> <li>• Benefiting people and limiting harm.</li> <li>• Prioritizing the disadvantaged.</li> <li>• Equal moral concern.</li> </ul>
Emanuel et al. (2020b)	<ul style="list-style-type: none"> <li>• Maximizing benefits (Save the most lives and life-years): Highest priority.</li> <li>• Treating people equally: Less used in the COVID-19 pandemic.</li> <li>• Promoting and rewarding instrumental value (benefit to others): High priority.</li> <li>• Giving priority to the worst off: Used with maximizing benefits.</li> </ul>
Bollyky et al. (2020)	<ul style="list-style-type: none"> <li>• Flexible, Trusted Governance.</li> <li>• Adequate, Predictable Financing.</li> <li>• Open Collaboration and Evidence-Based, Health-Driven Allocation.</li> <li>• Promoting the common good.</li> </ul>
Toner et al. (2020)	<ul style="list-style-type: none"> <li>• Treating people fairly and promote equity.</li> <li>• Promoting legitimacy, trust, and a sense of ownership in a pluralistic society.</li> </ul>
Gupta & Morain (2021)	<ul style="list-style-type: none"> <li>• Central goals: reducing morbidity and mortality, minimizing additional economic and societal burdens, and narrowing health inequalities.</li> <li>• Prioritization approaches: most vulnerable to morbidity and mortality, ensuring life-cycle, people with instrumental value, ensuring equal access, reduction of the spread of COVID-19 infections.</li> </ul>

Bibbins-Domingo et al. (2021)	<ul style="list-style-type: none"> <li>• The greatest numbers of COVID-19 cases, hospitalizations, and deaths per capita within a region.</li> </ul>
Sadeghi et al. (2021)	<ul style="list-style-type: none"> <li>• Within countries: high-risk and vulnerable groups.</li> <li>• Globally: countries with high mortality and risk of transmission to others.</li> </ul>
Wouters et al. (2021)	<ul style="list-style-type: none"> <li>• Availability of vaccines where needed.</li> <li>• Supporting for multilateral initiatives to ensure timely global access.</li> </ul>
Lee et al. (2021)	<ul style="list-style-type: none"> <li>• Highest risk of contracting &amp; transmitting, not based on legal residence.</li> </ul>
Weintraub et al. (2021)	<ul style="list-style-type: none"> <li>• Interrupting transmission of the pathogen, minimizing disease burden, and maximizing societal functioning.</li> </ul>

Source: The authors' own literature review.

In general, the literature review shows that maximizing benefits, minimizing disease burden, and prioritizing high-risk and vulnerable groups were the fundamental principles and values of vaccine allocation in both the local and global scopes (Emanuel et al., 2020; Sadeghi et al., 2021). Scholars and policy-makers defined prioritization criteria and priority groups for COVID-19 vaccine distribution based on these ethical dimensions (NASEM, 2020; WHO, 2020a; Hale et al., 2020; Ritchie et al., 2021; Craxi et al., 2021). Various actions were encouraged to ensure the fair and effective distribution of COVID-19 vaccines and save more people, such as the intellectual waiver, vaccine and medical equipment donation, and financial support (Burki, 2021). The COVID-19 Vaccines Global Access (COVAX) was developed to ensure the fair allocation of COVID-19 vaccines with the initial target of delivering 2 billion doses by the end of 2021. The main goals of COVAX were to offer doses for at least 20% of populations; provide a diverse and actively managed portfolio of vaccines, deliver vaccines, and medical equipment as soon as they were available; end the acute phase of the outbreak; and rebuild economies (WHO, 2021). The inequality in the distribution of the COVID-19 vaccine can be determined by various determinants that were classified into four macro determinants, including economic factors (stability and country's economic status, Gross Domestic Product per capita, financial support, and human development index), infrastructure and health system, legal and political, and epidemiologic and demographic factors; and micro determinants, including economic, demographic, and social characteristics (Bayati et al., 2022).

While the ethical dimensions of COVID-19 vaccine allocation between groups within a country (local or micro level) were widely agreed upon and applied, the ethical principles of vaccine allocation between countries (global or macro level) were highly debatable. The ethical debate surrounded whether to prioritize boosters in the most affected countries or the first doses globally. On 12 September 2021, over 5.8 billion doses had been globally administered, with 74.3 doses per 100 people; over 2.2 billion people had been vaccinated, accounting for 28.26% of the population; and over 1.4 billion people had been fully vaccinated, accounting for 17.96% of the population (Mathieu et al., 2021; Covidvax, 2021). However, only 1.9% of people in low-income countries had received at least one dose, whereas many wealthier countries started administering boosters for their people, especially older adults and people with weak immune systems (Mathieu et al., 2021; Guardian, 2021a). Until the pandemic's peak, COVAX could deliver 280 million COVID-19 vaccines to 141 participants (GAVI, 2021). Thus, COVAX could not achieve its initial targets of vaccine delivery and global vaccination at that time. In addition, the facility was supposed to be shunned by rich countries and failed to satisfy the needs of the poorest countries (Guarascio, 2021). At the peak of the COVID-19 pandemic, many countries had started administering boosters while many other nations (not only wealthy countries, such as Argentina, China, Indonesia, Philippines, Thailand, and Cambodia) had plans to make the booster shots for their people, especially older adults and people with weak immune systems (Guardian, 2021a; Reuters, 2021). World Health Organization (WHO) called the world's wealthiest countries to delay rolling out booster shots before at least 10% of the world is vaccinated (Guardian, 2021b). However, it was also said that these countries could do both; there was enough vaccine for their population and donation (Guardian, 2021a).

There are various studies on the ethical dimensions and principles for the COVID-19 vaccine allocation between groups within a country (micro level), and scholars and policy-makers have widely agreed upon and applied them. However, there is a dearth of studies on the ethical

dimensions and principles for vaccine allocation between countries (global or macro level). This study initially aims to investigate how COVID-19 vaccines were allocated at the macro level (cross-country analysis) and whether the global distribution of the vaccine was fair and effective according to the reviewed ethical dimensions at the peak of the COVID-19 pandemic by using a quantitative method, i.e., Spearman correlations and the national data of the COVID-19 pandemic, vaccinations, and economic indicators. The article then proposes and discusses a mechanism to optimally distribute scarce public goods for future events based on the lessons from the COVID-19 vaccine allocation from the quantitative results and the previous studies. This study can have significant implications and background for public health workers, decision-makers and policy-makers, scholars, and all relevant stakeholders involved in vaccine and SPGs allocation strategy programs.

## 2. Conceptualization and research design

This study proposes three concepts and several variables for the quantitative analysis of how COVID-19 vaccines were globally allocated between countries. The first concept is *the COVID-19 pandemic*, with variables of cases and deaths that can be defined and measured by the numbers of total cases (*TC*), total cases per population (*TCP*), total deaths (*TD*), and total deaths per population (*TDP*). The second concept is *the vaccine allocation*, with variables of doses and vaccinated people that can be defined and measured by total vaccinations (*TV*), people-vaccinated (*PV*), people-fully-vaccinated (*PFV*), total-vaccinations-per-hundred (*TVP*), people-vaccinated-per-hundred (*PVP*), and people-fully-vaccinated-per-hundred (*PFVP*). The third concept is *the wealth*, with variables of the gross domestic product per capita (*GDPp*) and human development index (*HDI*). The literature indicates that maximizing benefits, minimizing disease burden, and prioritizing high-risk and vulnerable groups are the ethical dimensions, values, and principles of fair and effective vaccine allocation. In the global scope, these fundamental principles can be defined as reducing coronavirus infections and mortality. Hence, COVID-19 vaccines and vaccine allocation for the countries with more significant numbers of total cases, total cases per population, total deaths, and total deaths per population can be considered fair and effective. Hypothesis 1 can be stated as follows:

*Hypothesis 1: The more vulnerable countries with more cases and deaths could obtain more COVID-19 vaccines and vaccine allocation.*

In other words, there should be significant and positive relationships between the variables of the COVID-19 pandemic and the variables of the vaccine allocation. Moreover, another research question is whether rich countries have got more COVID-19 vaccines and vaccine allocation. Hypothesis 2 can be presented as follows:

*Hypothesis 2: The wealthier countries with higher GDPp and HDI could obtain more COVID-19 vaccines and vaccine allocation.*

This study empirically assessed the relationships between the COVID-19 pandemic variables (including *TC*, *TCP*, *TD*, and *TDP*), the vaccination variables (including *TV*, *PV*, *PFV*, *TVP*, *PVP*, and *PFVP*), and the wealth variables (including *GDPp* and *HDI*) by using Spearman correlation and the secondary data. The secondary data was obtained from Ourworldindata, Worldometers, Covidvax, and WHO, including panel data and cross-sectional data. The panel data is the daily data on indicators or variables of the COVID-19 pandemic and the vaccine allocation of all countries since the beginning of COVID-19 until 12 September 2021, with 115,892 observations. The cross-sectional data is the aggregation data on indicators or variables of the COVID-19 pandemic and the vaccine allocation of all countries on 12 September 2021. The secondary data were analyzed by using the SPSS software to identify the relationships between these concepts and variables.

### 3. Results and discussion

*Was the allocation of COVID-19 vaccines fair and effective at the peak of the pandemic?*

Pearson and Spearman correlations were used to measure the relationship between the different variables of the three concepts. Both correlations indicate the significantly positive associations between the COVID-19 pandemic, vaccination, and wealth variables. However, the One-Sample Kolmogorov-Smirnov Test was used to analyze the normal distributions of these variables, and the result shows that these variables are non-normally distributed (P-value < 0.01). Therefore, this study employed Spearman correlation and its results to explain the relationships between variables. The findings from panel data are mainly presented in this article, while the results from cross-sectional data are used to enhance the findings and understand vaccine distribution in total.

*The relationship between the COVID-19 pandemic and the vaccine allocation:*

The results showed that TC and TD had significantly strong positive relationships with TV, PV, and PFV. In other words, countries with more significant numbers of people infected with and died of COVID-19 received significantly higher numbers of vaccines and vaccinations. Moreover, the associations of TCP with TVP, PVP, and PFVP were moderately positive. These results indicated that the countries with more cases per population obtained relatively higher rates of vaccines and vaccinations. However, TDP had weak positive relationships with TVP, PVP, and PFVP. The potential explanation is that COVID-19 vaccines were used more in the countries with higher death rates, but COVID-19 vaccines could also reduce deaths simultaneously. Overall, the relationships between infection and vaccination variables were stronger than between death and vaccination variables. Additionally, the empirical results showed that vaccines positively affected the COVID-19 pandemic and could reduce the death rate rather than the infection rate (Table 1).

*The relationship between the COVID-19 pandemic and the vaccine allocation with the wealth:*

There were positive relationships between the wealth and the COVID-19 pandemic variables. This result meant that the wealthier countries suffered more consequences from the COVID-19 pandemic. Surprisingly, the associations between the wealth and the vaccine allocation variables were positive but relatively weak. These findings indicated that the wealthier nations might not have notably more vaccinations at all times during the *COVID-19 pandemic*. They could receive more vaccines, but they also encountered more COVID-19 infections and deaths (Table 1).

*Results from the cross-sectional data in aggregation:*

Generally, the relationships between the COVID-19 pandemic variables and vaccination variables in the statistical analysis using cross-sectional data were higher than those in the statistical analysis using panel data. The TC, TCP, and TD variables had significantly strong positive relationships with the TV and TVP variables. In other words, countries with more cases and deaths achieved more vaccines and vaccinations. Notably, wealth variables had significantly strong positive relationships with coronavirus and vaccination variables. The findings proved that the wealthier countries could have higher coronavirus cases and deaths and obtain higher vaccination rates in aggregation (Table 2).

*In summary*, the statistical analysis showed that the global allocation of vaccines was relatively fair and optimal according to the ethical dimensions, values, and principles. Countries that suffered more severe consequences of the COVID-19 pandemic, with more cases and deaths, obtained more vaccines and vaccinations. Moreover, wealthier countries might receive more vaccines and vaccinations but suffer more severe consequences of the COVID-19 pandemic. These COVID-19 vaccine allocation results could be determined by market factors (e.g., supply, demand, and price) and non-market mechanisms (e.g., priority lists, ethical dimensions, and political attributes) (Condorelli, 2013; Hoang, 2022). Additionally, COVID-19 vaccines and scarce health public goods are special resources that should be affected by many aspects and issues. Their development and

allocation can be affected by various factors, such as ethical standards, international organizations and facilities (e.g., COVAX, WHO, UN), vaccine nationalism and apartheid, vaccine diplomacy and partnerships, global and regional politics, vaccine charity and liberty, science and technology, and vaccine production and consumption capacities (Wouters et al., 2021; Su et al., 2021; Sparke & Levy, 2022; Hoang, 2022). As a result, a feasible, fair, and optimal allocation mechanism of COVID-19 vaccines and scarce public goods need to include and balance market elements, ethical dimensions, political attributes, and other factors.

**Table 2.** Relationships between variables, findings from panel data over time.

		TC	TD	TCP	TDP	TV	PV	PFV	TVP	PVP	PFVP	GDP <sub>p</sub>	HDI
TC	Correlation Coefficient	1.000											
	Sig. (2-tailed)												
	N	110267											
TD	Correlation Coefficient	.958**	1.000										
	Sig. (2-tailed)	0.000											
	N	99641	99642										
TCP	Correlation Coefficient	.753**	.621**	1.000									
	Sig. (2-tailed)	0.000	0.000										
	N	109685	99072	109685									
TDP	Correlation Coefficient	.726**	.735**	.935**	1.000								
	Sig. (2-tailed)	0.000	0.000	0.000									
	N	99072	99073	99072	99073								
TV	Correlation Coefficient	.716**	.667**	.168**	.207**	1.000							
	Sig. (2-tailed)	0.000	0.000	0.000	0.000								
	N	23514	23392	23514	23392	24921							
PV	Correlation Coefficient	.747**	.696**	.171**	.231**	.996**	1.000						
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000							
	N	22598	22477	22598	22477	23698	23882						
PFV	Correlation Coefficient	.716**	.656**	.165**	.205**	.967**	.953**	1.000					
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000						
	N	19724	19650	19724	19650	20847	20853	20928					
TVP	Correlation Coefficient	.144**	.066**	.512**	.336**	.441**	.398**	.428**	1.000				
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000					
	N	23514	23392	23514	23392	24921	23698	20847	24921				
PVP	Correlation Coefficient	.134**	.062**	.522**	.352**	.423**	.392**	.414**	.994**	1.000			
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
	N	22598	22477	22598	22477	23698	23882	20853	23698	23882			

PFVP	Correlation Coefficient	.072**	-0.006	.511**	.309**	.296**	.255**	.441**	.978**	.955**	1.000		
	Sig. (2-tailed)	0.000	0.427	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	N	19724	19650	19724	19650	20847	20853	20928	20847	20853	20928		
GDPp	Correlation Coefficient	.298**	.248**	.425**	.402**	.148**	.129**	.107**	.398**	.411**	.338**	1.000	
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	N	101106	91341	101106	91341	21586	20618	17981	21586	20618	17981	103058	
HDI	Correlation Coefficient	.307**	.275**	.441**	.441**	.163**	.155**	.118**	.365**	.378**	.299**	.945**	1.000
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	102200	92380	102200	92380	21370	20462	17805	21370	20462	17805	100695	102895

\*\* . Correlation is significant at the 0.01 level (2-tailed). Source: Authors' own analysis based on the data of Mathieu et al. (2021) and Worldometers (2021).

**Table 3.** Relationships between variables, findings from cross-sectional data (aggregation data).

		TC	TD	TCP	TDP	TV	TVP	GDPp	HDI
TC	Correlation Coefficient	1.000							
	Sig. (2-tailed)								
	N	201							
TD	Correlation Coefficient	.958**	1.000						
	Sig. (2-tailed)	0.000							
	N	193	193						
TCP	Correlation Coefficient	.475**	.339**	1.000					
	Sig. (2-tailed)	0.000	0.000						
	N	201	193	201					
TDP	Correlation Coefficient	.536**	.555**	.874**	1.000				
	Sig. (2-tailed)	0.000	0.000	0.000					
	N	193	193	193	193				
TV	Correlation Coefficient	.880**	.835**	.225**	.265**	1.000			
	Sig. (2-tailed)	0.000	0.000	0.001	0.000				
	N	201	193	201	193	201			
TVP	Correlation Coefficient	.150*	0.088	.605**	.457**	.244**	1.000		
	Sig. (2-tailed)	0.034	0.223	0.000	0.000	0.000			
	N	201	193	201	193	201	201		
GDPp	Correlation	.202**	0.095	.628**	.460**	.232**	.831**	1.000	
	Sig. (2-tailed)	0.007	0.207	0.000	0.000	0.002	0.000		
	N	181	177	181	177	181	181	181	
HDI	Correlation	.445**	.323**	.705**	.571**	.467**	.841**	.946**	1.000
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	178	175	178	175	178	178	178	178

\*\* . Correlation is significant at the 0.01 level (2-tailed). \* . Correlation is significant at the 0.05 level (2-tailed). Source: Authors' analysis based on the data of Mathieu et al. (2021) and Worldometers (2021).

#### *Why did COVAX miss its initial vaccine delivery targets?*

COVAX had unparalleled and idealistic goals to generate a global procurement mechanism to provide COVID-19 vaccines to all countries reasonably, and it could make notable contributions to controlling the COVID-19 pandemic and protecting human health (Usher, 2021). The facility can somewhat be similar to a centrally planned and socialist economic system. However, the goals could only be partially achievable by a central plan. COVAX and global organizations cannot decide and perform all functions of different actors in the markets of vaccines and SPGs. As a result, the facility could ship only 280 million COVID-19 vaccines, only 4,7% of the world vaccine distribution, to 141

countries until 12 September 2021, the pandemic peak (GAVI, 2021). The number was far from its initial targets, and COVAX was said to miss its initial goal. Nevertheless, the author supposes that COVAX is still thriving in its core goals and is crucial in controlling the pandemic. The main reasons for the miss could be summarized as follows: (1) The COVID-19 pandemic was unpredictable, unknown, and complicated; (2) The global demand for vaccines was very high while the vaccine supply was limited; (3) The wealthier countries were also the centers of the catastrophe; thus, they must vaccinate their population first; (4) COVAX's initial goals seemed to be too big and idealistic, and the principle of perfectly equal treatment may be unfeasible and ineffective in practice; (5) Many lower-income countries could control the pandemic by the PHSMs; hence, their vaccine demands were not very urgent; (6) Coronavirus vaccine is still a commodity; thus its allocation must depend on the market mechanism, supply and demand; and (7) Besides charity, the suppliers had their own diplomatic and economic purposes when devoted or provided vaccines as special goods.

#### *Fair and optimal allocation mechanism for COVID-19 vaccines and SPGs*

Based on the empirical analysis, the literature review, and the COVAX situation, the author proposes a global allocation framework for COVID-19 vaccines and SPGs with three degrees that can combine the roles of markets and the interventions of the national governments and international organizations to ensure ethical standards, fairness, and effectiveness. In other words, the allocation mechanism is feasible, fair, and effective to save most, minimize harm, and maximize benefits. Similar to the socialist-oriented market economic system in contemporary Vietnam (Nguyen, 2022; Ho & Nguyen, 2021), this optimal allocation mechanism contains glorious and practical goals based on the market mechanism, the support and monitoring of international organizations, and the interventions of national governments to remedy market failures. A socialist market-oriented economy is a multi-sector commodity economy that operates by market mechanisms and follows a socialist orientation to achieve the goals of increasing people's income and social welfare, becoming a strong, democratic, and civilized country; addressing market failures; and ensuring fair, inclusive, and sustainable development (Nguyen, 2012; Nguyen, 2022; Ho & Nguyen, 2021). Therefore, the optimal allocation framework can be used to fairly and effectively allocate COVID-19 vaccines and scarce public goods in future pandemic events (Table 4).

**Table 4.** Optimal allocation mechanism for COVID-19 vaccines and SPGs at the global level.

<b>What</b>	<b>Who</b>	<b>How</b>
<i>Emergency</i>	Most dangerous and vulnerable groups and regions at crisis peak	- Available supply of vaccines and SPGs. - Immediate and urgent delivery. - Free and non-optional goods.
<i>Priority</i>	High-risk and worse-off groups and regions during a pandemic	- Prompt supply of vaccines and SPGs. - Quick and timely delivery. - Special prices and optional goods.
<i>Market</i>	Low-risk and regular groups and regions during a pandemic	- Planned supply of vaccines and SPGs. - Timely and proper delivery. - Market prices and optional goods.

Source: The author's construction.

#### Emergency:

Vaccines and SPGs must be the first and instantly allocated to the most dangerous and worst-off groups and regions in the COVID-19 uncontrollable crisis and at the peak of the pandemic to save most and minimize harm (Persad et al., 2009; WHO, 2020b; Emanuel et al., 2020b). In this situation, there are sudden and tremendous increases in injection, death, and seriously vulnerable people within these regions. International organizations and national governments play an essential role in this situation, and they need to be prepared for these situations with the availability of vaccines and SPGs for immediate and urgent delivery. These people in this situation can receive free vaccines and SPGs, but cannot choose between types, brands, and origins of goods.

**Priority:**

Essential workers, high-risk staff, and worse-off groups in the controllable pandemic and people in the uncontrollable crisis should be prioritized for vaccinations and interventions to maximize the total benefits (Persad et al., 2009; WHO, 2020b; Emanuel et al., 2020b). Vaccines and SPGs should promptly be supplied with quick and timely (planned) delivery. The payment and option of goods are dependent on providers and receivers. Global organizations can support and play the essential roles of the connector or the central distributor.

**Market:**

Coronavirus is less dangerous for people in controllable COVID-19 situations by the PHSMs and for strong people in the COVID-19 pandemic. Hence, allocating vaccines and SPGs for these people and regions is not very urgent. Vaccine and SPGs delivery to these people and regions should depend on the market mechanisms to treat people fairly with equal moral concern (Condorelli, 2013; Persad et al., 2009; WHO, 2020a; Emanuel et al., 2020a). However, the national governments should have plans to vaccinate their citizens and be prepared for worse occurrences early. These people and regions can purchase COVID-19 vaccines and SPGs according to the market mechanisms with market prices and free goods options. Global organizations can be the connector or central distributors for COVID-19 vaccines and SPGs.

**4. Conclusions**

Generally, allocating COVID-19 vaccines and scarce public goods in crisis periods is a complex and sensitive decision for leaders and managers of any governments, firms, and organizations. The literature review showed that the ethical dimensions, values, and principles for the COVID-19 vaccine and SPG allocation between groups within a country (micro level) have been widely agreed upon and globally applied by policy-makers, practitioners, and scholars. However, the allocation of COVID-19 vaccines and SPGs across countries (global or macro level) is more complicated and highly debatable. This study tries to understand how COVID-19 vaccines were allocated at the macro level (cross-country analysis) and whether the global distribution of the vaccine was fair and effective according to the reviewed ethical dimensions at the peak of the COVID-19 pandemic, and then proposes a mechanism to optimally distribute scarce public goods for future events based on the lessons from the COVID-19 vaccine allocation.

The empirical findings indicated that the global allocation of COVID-19 vaccines could be considered fair and effective. Countries with more cases and deaths could obtain more vaccines and vaccinations. In other words, the attributes of the COVID-19 pandemic significantly impacted the allocation of vaccines. Wealthier countries might receive more vaccines and vaccinations but also suffer more severe consequences of COVID-19. However, as the limitations of this analysis, it should be cautious about affirming the conclusion of these relationships and the fair vaccine allocation since there could be a coincidence and the data understatement or shortage in some countries.

The development and allocation of vaccines and SPGs between countries are determined by various factors, including ethical standards, international organizations and facilities (e.g., COVAX, WHO, UN), vaccine nationalism and apartheid, vaccine diplomacy and partnerships, global and regional politics, vaccine charity and liberty, science and technology, and vaccine production and consumption capacities. Therefore, a new allocation mechanism of COVID-19 vaccines and SPGs is needed to include and balance these factors. This study built a fair and optimal allocation mechanism for COVID-19 vaccines and SPGs consisting of three levels, i.e., Emergency, Priority, and Market. International organizations, e.g., COVAX, WHO, and UN, play vital roles in promoting and monitoring the development, production, and distribution of vaccines and SPGs; supporting vulnerable groups and low-income countries; promulgating regulations, standards, and guides; and controlling pandemics. Therefore, they need more power, funds, and resources to complete these essential roles and functions.

The findings can provide crucial implications for global decision-makers, policy-makers, and all relevant stakeholders involved in vaccine and SPGs allocation strategy programs. Scholars and practitioners can extend the SPG allocation framework with specific principles and mechanisms in different cases or events. However, the study still has limitations in that it could not empirically identify the determinants of allocation of vaccines and SPGs at the macro level or across countries due to the lack or insufficiency of data.

### Abbreviations

COVID-19 Vaccines Global Access - COVAX  
 Gross Domestic Product Per Capita - GDPp  
 Human Development Index - HDI  
 People Fully Vaccinated - PFV  
 People Fully Vaccinated Per Hundred - PFVP  
 People Vaccinated - PV  
 People Vaccinated Per Hundred - PVP  
 Scarce Public Goods - SPGs  
 Total Cases - TC  
 Total Cases Per Population - TCP  
 Total Deaths - TD  
 Total Deaths Per Population - TDP  
 Total Vaccinations - TV  
 Total Vaccinations Per Hundred - TVP  
 World Health Organization - WHO

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